Urban Mobility: Car2x Communication - Qualitative Analysis of Chances and Challenges

Masterarbeit

zur Erlangung des akademischen Grades „Master of Science (M. Sc.)" im Studiengang Wirtschaftswissenschaft der Wirtschaftswissenschaftlichen Fakultät der Leibniz Universität Hannover

vorgelegt von

Name: Abraham Vorname: Lennart

[redacted] [redacted] [redacted] [redacted]

Prüfer: Prof. Dr. Michael H. Breitner

Hannover, den 28.09.2017

Table of content

1 Introduction

1.1 Motivation and Relevance

Mobility is a fundamental human need and key to the success of a dynamic economy. For the past hundred years, the automotive industry has developed groundbreaking technological innovations, leading to a safer, cleaner and more comfortable transportation and mobility environment. Modern vehicles are equipped with highly sophisticated technologies in order to provide active and passive safety to all road users.

However, urbanization, growing motorization and increasing mobility pose challenges to existing transportation systems. In 2015, the European Union accounted for 26.000 fatalities in relation to road traffic (Eurostat, 2016). The 2010 published *White Paper on European Transport Policy* sets the general objective of the European Union to reduce road fatalities by 50% until 2020 (European Union, 2011). Yet, the amount of road fatalities has decreased by only 17% compared to 31.500 cases counted in 2010.

Additionally, cities are subject to an increase in traffic density. In 2016, 694.000 traffic jams were counted on German roads, accounting for 1,3 million kilometres congestion length and 419.000 hours of traffic jam (ADAC, 2017). In conurbations such as Stuttgart or Heilbronn, the average driver spends over 45 hours a year in traffic jam (INRIX, 2017). Especially freight transport is continuously gaining in significance. Due to its role as a transit country, freight transport in Germany is expected to increase by 40% in 2025. In the same period, emerging economics like the BRIC states are forecasted to see an increase in freight transport by 80% (VDA, 2012). As a consequence of the globally accelerating passenger and freight transport, air and climate conditions are increasingly burdened. In 2015, the transport sector constituted for 18% of the overall greenhouse gas emissions in Germany (Umweltbundesamt, 2017).

Fluid and reliable traffic flow, as well as safe road traffic are considered main cornerstones for growth and prosperity of any country. Against the background of finite resources and climate change, the satisfaction of mobility needs becomes increasingly challenging. It is argued that future transportation will be shaped by digitalization and the exchange between vehicles and their surroundings. Whereas technological innovations and developments were incremental for the most time throughout history, the automotive industry appears to be on the cusp of revolutionary change. The opportunities of digitalisation will enable intelligent transportation systems, allowing vehicles to intelligently connect to other transport users and infrastructure. In this context, Car2x communication is considered a major breakthrough technology in or-

der to cope with the challenges of urban mobility. The technology enables vehicles to communicate with each other, for instance by exchanging information on approaching obstacles or safety-critical situations. By receiving information on traffic light phases and dynamic traffic signs, vehicles further increase their range of view and are no longer limited to its direct range of detection. Car2x communication is expected to provide significant potentials to increase active road safety and traffic efficiency, which is accompanied by environmental benefits. Moreover, the connection between vehicles themselves and their surrounding infrastructure enables applications and use cases in order to enhance comfort and infotainment opportunities. With regard to higher levels of automated driving, the communication between vehicles and infrastructure is considered a game changer. *"For the first time, our cars are exchanging data with traffic infrastructure in real time. Drivers can adapt their behaviour to the situation and move through city traffic in a much more relaxed and controlled way,"* says Andreas Reich, head of Electronics Pre-Development at AUDI AG. *"We increase energy efficiency when we connect our Audi models to smart cities. Further Vehicle-to-Infrastructure (V2I) services will follow, making the car into an interactive mobile device. We see autonomous driving as the end of this development."* (Audi, 2016).

1.2 Objectives and Structure of the Thesis

Greater road safety, increased mobility and propagated environmental protection lead to an increased public welfare. Moreover, Car2x communication provides considerable economic potential. The variety of theoretical use cases and applications offers considerable economic potential to OEMs, suppliers and telecommunication operators. Industrial boundaries are blurring, distribution channels are developed and new business models emerge.

However, not every use case is expedient, not every application builds a profitable business case. Moreover, Car2x is subject to a vast number of technological, legal and societal considerations. Despite its inevitable relevance, Car2x communication has rarely been covered comprehensively in recent literature yet. Against this backdrop two research questions are derived:

- *"What are the chances and challenges of Car2x communication?"*

- *"How can Car2x communication contribute to managing the complex challenges of urban mobility?"*

In order to cope with the research questions proposed, essential theoretical foundations are required, which are presented in chapter two. Hence, the Car2x system architecture will be portrayed, including its components and communication channels as well as common forwarding and messaging types. Moreover, a selection of theoretical Car2x use cases and applications will be given, followed by an overview on current research activities and first market activities for Car2x. In the third chapter, the conceptual framework and methodology of the empirical work will be outlined. This thesis incorporates eleven in-depth expert interviews with representatives of OEMs, suppliers, telecommunication industry, research, consultancy and authorities. Based on the interviews, chapter four presents a detailed analysis of the results obtained with regard to requirements and potentials of Car2x communication. The fifths chapter contains a substantial discussion of selected relevant aspects elaborated during the results analysis as well as recommendations for action in practice. Moreover, limitations of this study are described. The thesis closes with a conclusion and outlook.

6 Conclusion and Outlook

The main purpose of this thesis was to examine the various chances and challenges of C2C and C2I communication in the urban environment. Eleven in-depth expert interviews were conducted, including representatives of Daimler AG, Volkswagen Nutzfahrzeuge, Audi AG, MAN Bus & Truck AG, Continental AG, Robert Bosch GmbH, Advanced Telematic Systems, Nokia Solutions and Networks Deutschland GmbH, BLIC GmbH, the CAR 2 CAR Communication Consortium and the City of Hannover. Hence, the study covered each industry and sector involved in the implementation of Car2x communication. Based on the conceptual framework, the interviews revealed requirements to Car2x applications on the one hand, including strategic, economical, system, organizational, legal and standardization requirements. Building on these constraints, this thesis compiled benefits of C2C and C2I with regard to traffic efficiency and safety, sustainability, accessibility and new emerging business opportunities.

Industry and research have the opportunity to address the continuing challenges of urban mobility by means of Car-to-Car and Car-to-Infrastructure. Its first task will be to derive concrete measures for each stakeholder to Car2x based on the obstacles and areas of action presented. In fact, Car2x is a joint project, which would be impossible to implement by a single industry or company. Instead, it requires collaborative effort across industries in order to define and cope with the diverse areas of action. In that regard, the development of profitable and appropriate business cases will be paramount. From a technical perspective, Car2x has already proven to be feasible today. Long-standing field studies such as the sim^{TD} trial, but also first practical implementations by Mercedes-Benz and Audi have proven the every day practicability of Car2x communication. Instead, it is essential to create remunerative and sustainable business models taking each stakeholder into account.

By deploying C2C and C2I the reduced risk of accidents and fatalities will be exchanged for an associated data risk. Both OEMs and customers express privacy concerns with regard to Car2x, which need to be addressed in the future. Therefore, it requires an integrated communication between all industries involved and the respective customers.

In spite of these risks, the major consensus is that future mobility will significantly differ from the current. The merging of the automotive and telecommunication industry leads to increasingly blurring delimitation lines. This requires mutual understanding and growing cooperation.

Future mobility is becoming increasingly connected. The connection and communication between vehicles and their environment enables significant improvements in road safety, traffic efficiency and comfort. C2C and C2I in particular allow for en-

hanced traffic management and control, which in return offers opportunities for traffic flow optimization. Cooperative awareness furthermore enables vehicles to utilize road capacities more efficient, as for instance by tailgating. Especially for freight transport, platooning offers significant potentials for increased traffic flow.

Cooperative awareness further has considerable impact on active road safety. The declared goal of OEMs and suppliers is to approach the Vision Zero. By expanding the driver's field of view and issuing warnings of potential safety-critical situations, Car2x offers potential to reach ultimately the goal of accident-free driving. Increased road safety further means fewer accidents and traffic jams. This in return increased traffic flow and efficiency. Consequently, Car2x communication contributes to environmental protection and sustainability objectives, which is further enhanced by efficiency-optimized driving manoeuvres and anticipatory driving.

This study addressed selected important topics, which could not be pursued further in the course of this thesis. However, it may be worthwhile for future research to investigate in the following topics:

- **Over-the-air Updates**: which potentials do OTA updates offer with regard to connected mobility? What are the risks of distributing new software, configuration settings and encryption keys automatically?
- **Mixed Traffic**: the road towards connected mobility will involve a transition phase during which certain vehicles will be equipped with Car2x technology, whereas other traffic participants will remain unconnected. It will be important to develop approaches in order to cope with non-networked road users.